TO INVESTIGATE THE AFFECT OF PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF TIG WELDED 6351 ALUMINUM ALLOY BY ANOVA.

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ABSTRACT

Tungsten inert gas (TIG) Welding is an important component of many industrial applications. It is a type of arc welding process where Non-consumable tungsten electrode is used. An inert gas is used as a shielding gas to prevent the oxidation of weldment. The welding parameters play vital role in joining the work pieces by TIG welding. The objective of the project is to investigate the influence of welding parameters such as Welding current, gas flow rate, filler material and welding speed on mechanical properties of Aluminium 6351 alloy. The mechanical properties of weld joint are affected greatly with the variation of welding parameters. The output parameter looked into are Weld strength. The experiments are planned using Taguchi method. Then the analysis of the results was carried out by using the ANOVA in Minitab 16 to find which Process parameter has significant effect on output parameter.

KEYWORDS: TIG Welding, Aluminum 6351, Taguchi Method, ANOVA.

INTRODUCTION

Welding is a fabrication process that joins materials, usually metals or thermoplastics by causing coalescence. Gas tungsten arc welding, GTAW, also known as tungsten inert gas welding, is an arc welding process that uses a non consumable electrode to produce the weld. Weld area is protected from atmospheric contamination by a shielding gas (usually inert gas such as argon)

and a filler material is normally used. GTAW is most commonly used to weld thin sections of stainless steel and non ferrous metals such as aluminium, magnesium and copper alloys.
Aluminium based alloys have been widely used in automobile structures due to their unique properties such as high strength to weight ratio. The welding of aluminium and its alloys has always represented a great challenge for designers and technologists. As a matter of fact, lots of difficulties are associated to this kind of joint process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high coefficient of thermal expansion, solidification shrinkage and, above all, high solubility of hydrogen, and other gases, in molten state. Further problems can arise when attention is focused on heat-treatable alloys, since heat, provided by welding process, is responsible of the decay of mechanical properties; hence it is of outmost importance that the process of welding is carried out at optimum parameter levels to eliminate the above mentioned effects.

The present work is deals with finding out the effect of welding parameters welding current, voltage, gas flow rate on the weld strength of aluminium 6351 alloy. The experiments were planned using Taguchi methods and the analysis was carried using ANOVA in Minitab 16 software.

TABLE 1

Chemical composition of Al 6351 alloy

Al	Si	Mg	Mn
97.8	1.0	0.6	0.6

LITERATURE REVIEW

R Sudhakaran et al. [1] established a relationship between welding input parameters and depth of penetration for gas tungsten arc welding of 202 grade stainless steel plates. They also found that depth of penetration increases with increase in the gun angle this is due to preheating of the base metal is high a similar kind of effect is found with the increases and decrease of weld current.

Dong Min, Jun Shen et al**.** [2] studied the effects of heat input on the microstructures and mechanical properties of tungsten inert gas arc butt-welded AZ61 magnesium

A.Raveendra et al**.**[3] has performed experimental work on, selection of process parameters for non-pulsed & pulsed current GTAW welding of material EN19 having two different thickness, radiography, liquid Penetrate test were also done .It was observed that porosity increased with increase in thickness and pulse frequency. No defect was observed in the weldments welded with non-pulsed and pulsed current weldments during the liquid Penetrate test.

Indira Rani M et al. [4] has studied the mechanical properties of the weldments of AA6351 during the Tungsten Inert Gas Welding (TIG) with non-pulsed and pulsed current welding at different frequencies 3Hz and 7Hz. The radiography and mechanical properties of the weldments have been examined and compared. By applying pulse welding a better depth of penetration and fusion of filler material with parent metal is obtained and by this it improves strength and ductility of weldments. The performance of pulsed current GTAW is better than non -pulsed current welding.

Q.Wang et al. [5] studied the influences of parameters of tungsten inert gas arc welding on the morphology, microstructure, tensile property and fracture of welded joints of Ni-base super alloy and found that with the increase of welding current and the decrease of welding speed bring about the large amount of heat input in the welding pool and the enlargement of width and deepness of the welding pool.

Ahmed Khalid Hussain et al. [6] conducted Experiments on specimens of single v butt joint having different bevel angle and bevel heights made up of AA6351 Alloy taking welding speed, bevel height, bevel angle as the process parameters. and found that the depth of penetration of weld bead decreases with increase in bevel height of V butt joint. Tensile strength is higher with lower weld speed.

I.Uygur et al [7] conducted experiments on 3 mm thick sheets of commercially pure titanium and found that excellent mechanical properties are obtained with mid range of arc current due to uniform and fine grains inside fusion zone and HAZ compared with the others. The highest hardness values of the joint is obtained with the lowest arc current, due to the low heat input and cooling rate.

Palani.P.K et al**.** [8] studied the effect of TIG welding parameters like welding speed, current and gas flow rate on ultimate tensile strength and percent elongation in welding of Al-65032 Experiments were planned using Taguchi technique and mathematical models developed showed that welding speed has the most significant effect on both UTS and percent Elongation followed by welding current.

Nattapong Sonsuvit et al. [9] investigated the effects of TIG pulse welding parameters and nitrogen gas mixed in Argon shielding gas on weld bead formation and microstructure of weld metals of AISI 304L stainless steels at the 10-h welding position and found that When the weld pool is shielded by Ar gas mixed with 1 vol.% of nitrogen, the pulse current that gives rise to the weld bead shape correspond to DIN 8563 quality class BS (Ip*) can be determined for the welding speed up to 4 mm/s. The higher Ip* is required at the higher welding speed to avoid the lack of fusion. The mixing of nitrogen gas to Argon shielding gas lowers Ip*, and reduces the ratio of delta ferrite in the austenite matrix.

JunYan et al. [10] investigated the microstructure and mechanical properties of 304 stainless steel joints by tungsten inert gas (TIG) welding, laser welding and laser-TIG hybrid welding Using X-ray diffraction to analyze the phase composition, microstructure characters, tensile tests were performed and the fracture surfaces were analyzed. The results showed that the joint by laser welding had highest tensile strength and smallest dendrite size in all joints, while the joint by TIG welding had lowest tensile strength, biggest dendrite size.

EXPERIMENTAL WORK

The experimental work was carried out in 3 phases. In the first phase the process parameters and their levels were found out. This is done by examining various literature reviews and also by using welding calculators such as miller welding calculator, then the experiments were planned using the Taguchi method.

Before going further in our discussion it is important to know what Taguchi methods are. The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there are intermediate number of variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly.

The Taguchi arrays can be derived or looked up. Small arrays can be drawn out manually; large arrays can be derived from deterministic algorithms. The arrays are selected by the number of parameters (variables) and the number of levels (states). This is further explained later in this article. Analysis of the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic. The experiments designed using Taguchi techniques for the research is shown in table below.

TABLE 2

Experiments Designed Using Taguchi Techniques

Welding Current(I)	**Voltage(V)**	**Gas flow rate(F)**
130	10	4.7

130	12	5.19
130	14	5.66
135	10	5.19
135	12	5.66
135	14	4.7
140	10	5.66
140	12	5.19
140	14	4.7

The parameters welding current, voltage, gas flow rate each were taken at three levels and the appropriate orthogonal array for three parameters at three levels is an L9 orthogonal array shown in above table.

Second phase of the experiment is to perform welding according to above designed table of experiments, initially the aluminium sheet purchased is cut into pieces each of size 3X150X70MM using a shear cutting machine. Then edge preparation is done for welding a single groove butt joint. Now, the welding is carried out using a TIG Welding machine the gas used for welding is argon and the filler metal ER-4043 is used for welding. The welding parameters current, voltage and gas flow rate are adjusted as per the experiments designed using Taguchi methodology. The voltage and current are adjusted using the adjustable knobs present on the welding unit where as the gas flow rate is adjusted using a diaphragm regulator which consists of two circular gauges one indicating the pressure in the cylinder and the other gas flow rate.

FIGURE 1

Welded Pieces According To Experiments Designed

In the final phase the welded pieces are subjected to tensile tests on a universal testing machine. The welded pieces are cut according to ASTM standards to fit in the U.T.M Machine.

FIGURE 2

Testing Specimen

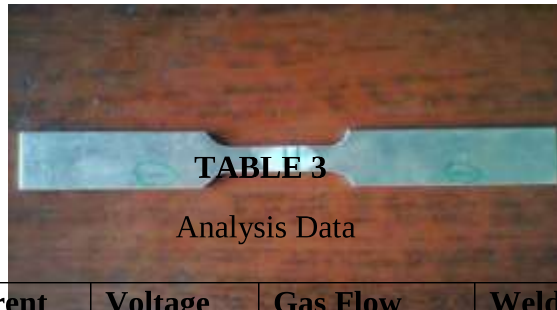


TABLE 3

Analysis Data

Current	**Voltage**	**Gas Flow Rate**	**Weld Strength**
130	10	4.70	197.62
130	12	5.19	200.35
130	14	5.66	199.40
135	10	5.19	185.90
135	12	5.66	215.56
135	14	4.70	179.36
140	10	5.66	203.23
140	12	5.19	174.81
140	14	4.70	194.47

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups), developed by R.A. Fisher. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the *t*-test to more than two groups. As doing multiple two-sample t-tests would result in an increased chance of committing a statistical type I error, ANOVAs are useful in comparing (testing) three or more means (groups or variables) for statistical significance. The various types of ANOVA are:

1. One Way ANOVA

2. Two Way ANOVA
3. Factorial ANOVA

Generally factorial ANOVA is commonly used to find the effect of three or more parameters effect is to be found out on response parameter or factor. Hence in this work factorial ANOVA is used to find out the effect of welding current, welding voltage and gas flow rate on the weld strength of 6351 aluminium alloy.

RESULTS AND DISCUSSION

It is necessary to check the assumptions of ANOVA before drawing conclusions. There are three assumptions in ANOVA analysis: normality, constant variance, and independence.

Normality – ANOVA requires the population in each treatment from which you draw your sample be normally distributed. The population normality can be checked with a normal probability plot of residuals. If the distribution of residuals is normal, the plot will resemble a straight line. The normal probability for the project is shown below which indicates that data is normally distributed.

Constant Variance – The variance of the observations in each treatment should be equal. The constant variance assumption can be checked with Residuals versus Fits plot. This plot should show a random pattern of residuals on both sides of 0, and should not show any recognizable patterns. A common pattern is that the residuals increase as the fitted values increase.

Independence – ANOVA requires that the observations should be randomly selected from the treatment population. The independence, especially of time related effects, can be checked with the Residuals versus Order (time order of data collection) plot. A positive correlation or a negative correlation means the assumption is violated. If the plot does not reveal any pattern, the independence assumption is satisfied.

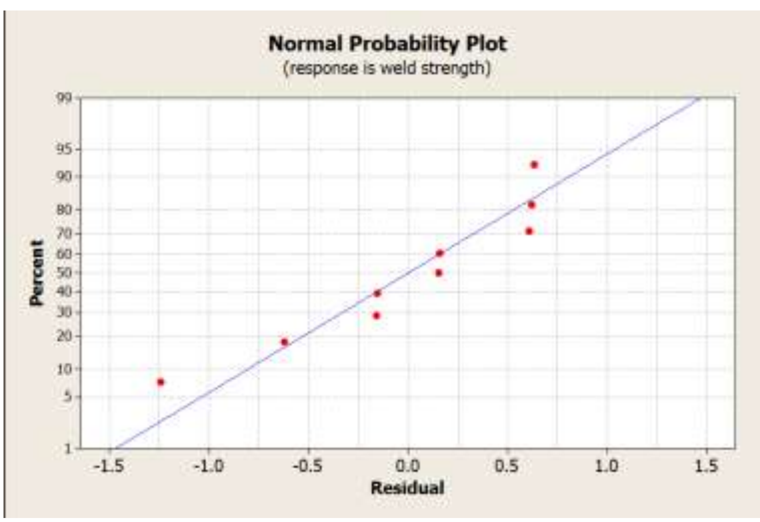
The normality plot of the residuals above shows that the residuals follow a normal distribution. Both plot of residuals versus fitted values and plot of residuals versus run order do not show any pattern. Thus, both constant variance and independence assumptions are satisfied.

P-value is a measure of how likely the sample results are, assuming the null hypothesis is true. P values range from 0 to 1. A small (<0.05, a commonly used level of significance) p-value indicates that the Power Level has statistically significant effect on the Etch rate. P-value indicates that the four main factors and 2 interactions have statistically significant effect on the response.

Pareto Charts- According to the following Normal plot of the standardized effects, factors c and AB have significant effect on the response. Pareto chart shows the same results. Since other terms are insignificant, we can drop these terms in the model.

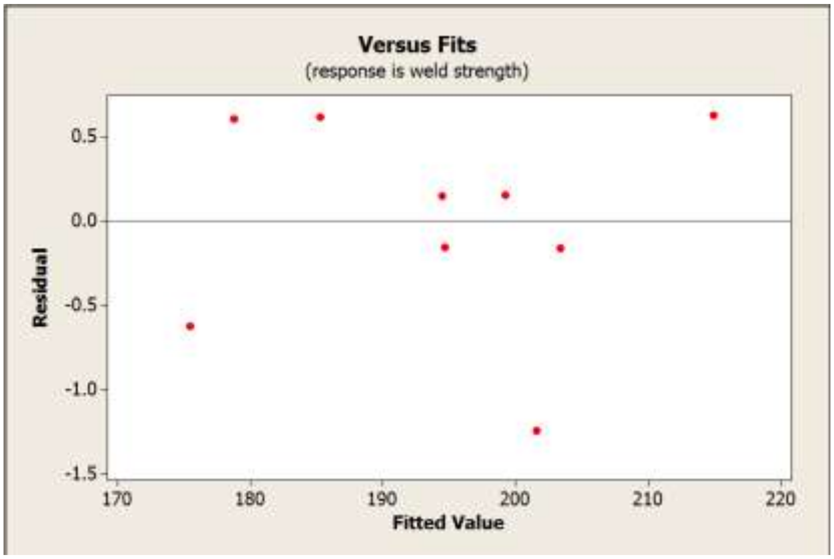
GRAPH 1

Normal Probability



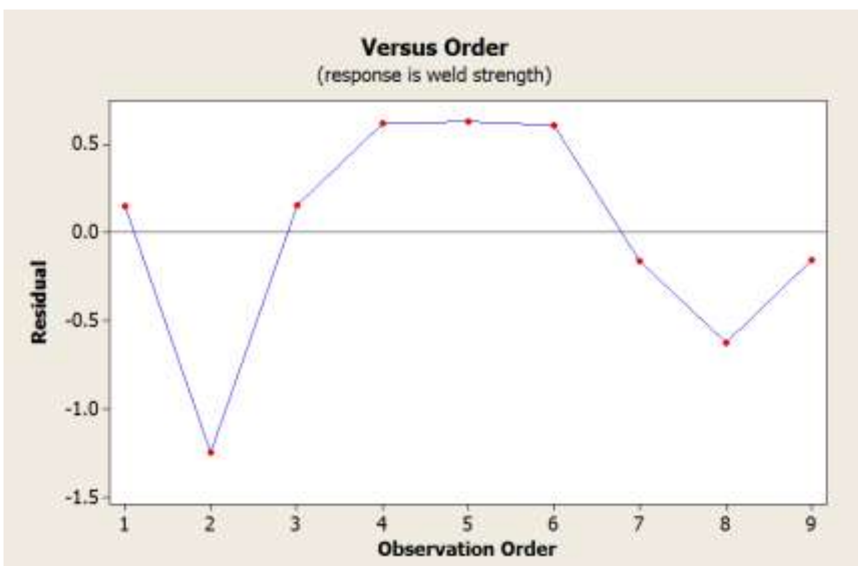
GRAPH 2

Residuals Versus Fits



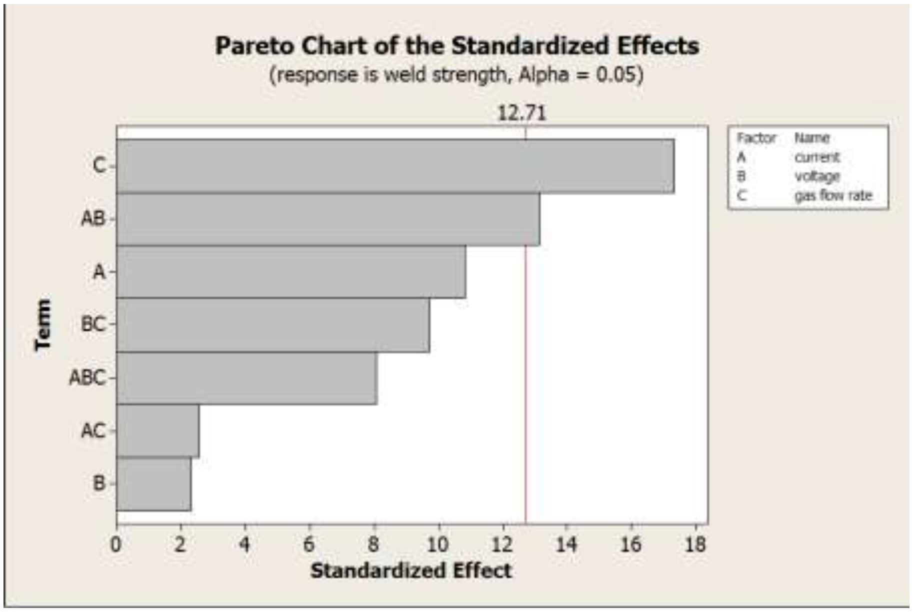
GRAPH 3

Residuals Versus Order



GRAPH 4

Pareto Chart of Standard Effects



CONCLUSIONS

Hence From the above graphs it is found that the factor C i.e the gas flow rate and the interaction AB have a significant effect on the weld strength of the welded joint. It can be seen from the experiments table that for the values of voltage, current and gas flow being highest the weld strength is also found to be highest among all.

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